Summary. 1. Emphasis has been placed upon the necessity of considering the pole effect in the redetermination of wave-lengths in international units.

2. The wave-lengths of these sensitive lines are not affected by a wide variation of density of the radiating vapor.

3. Their wave-lengths are independent of changes in temperature over the range of our observations.

4. For the lines considered the pole effect does not occur *in vacuo*, and in so far appears independent of electrical conditions.

5. The observed pole effect does not vary with wave-length in the same way as pressure shift, and cannot be explained as a pure pressure effect unless the pressure changes in certain definite ways with the wave-length.

[1] *Mt. Wilson Contr.* No. 61; *Astrophys. J.* **36**, 37 (1912).
[2] *Mt. Wilson Contr.* No. 58; *Astrophys. J.* **35**, 10 (1912).

INHERITANCE IN THE ASEXUAL REPRODUCTION OF HYDRA VIRIDIS

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Do heritable variations commonly occur among the offspring of a single individual multiplying asexually? May selection among such offspring produce strains differing in hereditary characters? The investigation here resumed is designed to contribute data toward the answer to these much debated questions.

A number of specimens of Hydra viridis, taken at random from wild populations, gave rise by asexual reproduction to clones differing from one another in their average number of tentacles and in other characters. As a test of whether such differences are the result of internal factors or of environmental differences two clones were bred in large numbers for a period of five months, during which time the members of the two clones were kept under environmental conditions as nearly as possible the same. Each polyp was kept in a separate culture dish and food was distributed uniformly to all. The number of tentacles was recorded at the time when the polyps began their independent life after separation from the parents (the initial number of tentacles), and records were kept, also, of changes in the number of tentacles of parents.

The two clones kept under parallel conditions gave the following results. The average number of tentacles of 1353 members of one

clone (A) bred during the first three months was 6.463 ± 0.013; the average number of tentacles of 1395 members of the other (D) was 5.793 ± 0.011; the difference between these averages is 0.724 ± 0.017. At the end of three months a single polyp was taken from each clone and used to found another clone. The average number of tentacles of the subordinate clone obtained in this way from clone A was 6.907 ± 0.026; that of the clone derived from D was 5.844 ± 0.029; the difference is 1.063 ± 0.039, in the same direction as before. At different times during the history of the clones the number of tentacles of the buds fluctuated considerably but the difference between the averages of the buds produced at the same time by the two remained fairly constant. The minimum difference in any one week of cultivation was 0.449 ± 0.042, the maximum difference, 1.063 ± 0.039. Small groups of polyps from the two clones were kept in mass cultures under partly controlled environmental conditions, such as reduced food supply. Under such conditions the difference persisted so long as the two clones were kept under the same environment.

These clones differed in other respects besides the average number of tentacles. The polyps of clone A were, on the average, more than twice as large as those of clone D, the average for the two being: A = 0.869 ± 0.021 cu. mm., D = 0.322 ± 0.022 cu. mm: the average difference is 0.547 ± 0.023 cu. mm. Polyps of clone A began to produce buds at an average age of 3.74 ± 0.074 days, those of clone D at 4.81 ± 0.10 days; a difference of 1.06 ± 0.13 days in the average age at reproductive maturity.

At no time during their history did the two clones show an identity of characters. There were no constant differences in the environmental conditions under which they were cultivated and it is certain that the differences between the clones were the result of some internal factors. The clones represented hereditarily diverse races. Other diverse races showing somewhat less well marked differences have been found and seem to be of rather frequent occurrence in wild populations. No direct evidence upon the origin of such diverse races or their relation to sexual reproduction has been obtained.

The inheritance of variations in the number of tentacles within the clone was studied by statistical methods and by the continued selection of variates. A comparison of the variations in the initial number of tentacles of parent and offspring by the use of the coefficient of correlation shows no significant resemblance between parent and offspring. The coefficients obtained are such as the following:

No. of Parents	*No. of Offspring*	*Coefficient of Correlation*
251	1395	0.0038 ± 0.018
78	439	-0.0342 ± 0.032
164	859	0.0011 ± 0.023
28	204	0.0314 ± 0.047
18	153	-0.2420 ± 0.051
51	154	-0.0750 ± 0.054

As is well known, the number of tentacles of Hydra changes during the life of the individual. When the number of tentacles of each bud is compared with the number born by the parent at the time when the bud was produced there is a slight correlation in the variations of parents and offspring. For the first clone recorded above this is 0.096 ± 0.016. There is also a slight positive correlation in the variations of the buds produced by a single parent, as is shown by the following:

No. of Pairings	*Fraternal Coefficient of Correlation*
12099	0.161 ± 0.004
10766	0.077 ± 0.006

A study of the relation of variations in the number of tentacles to environmental changes shows that unfavorable conditions tend to reduce, or to prevent increase in, the number of tentacles of parents and at the same time lead to a reduction in the number of tentacles of the offspring of these parents. Thus, wherever diversities of environment occur in cultures of Hydra there should be produced a likeness between parent and offspring that is not the result of heredity. To test this, the period of cultivation of the two clones giving the above fraternal correlations was divided arbitrarily into five-day periods and the buds produced within each of these periods were compared. From this comparison it appears that unrelated buds produced under like conditions of cultivation resemble each other as much as do the offspring from a single parent. The coefficients of correlation between the unrelated buds produced at the same time were:

No. of Pairings	*Coefficiont of Correlation*
95141	0.0774 ± 0.0015
101872	0.1313 ± 0.0014

It thus appears that the slight resemblance found between parent and offspring and between members of the same fraternity within the clone may be due either to an inheritance of variations or to the like action of environment upon individuals produced at nearly the same time. Statistical methods do not suffice to distinguish between the two possibilities.

Twenty-five variates from a single clone were selected for seven or more tentacles, and 25 for six or less, the mean of the clone lying between six and seven. Selection was continued for six or more generations. At the end of this time records were kept of all buds produced by the last selected generation. Those produced by parents from the series selected for few tentacles were found to have somewhat fewer tentacles than those from parents of the other series, but the difference appeared only in the first six buds and did not persist in the later buds produced by the same parents. The average number of tentacles of the first six and of later buds produced by the last selected generation is shown in the following table.

Buds of the Last Selected Generation

	AVERAGE OF ALL	FIRST SIX	LATER BUDS
Selected for many tentacles	6.695 ± 0.023	6.677 ± 0.029	6.712 ± 0.030
Selected for few tentacles	6.605 ± 0.026	6.460 ± 0.034	6.782 ± 0.037
Difference	0.095 ± 0.035	0.217 ± 0.044	−0.070 ± 0.047

Continued selection at first seemed to have produced a change in the hereditary character of the two groups but this did not persist even through a single generation. Complete regression appeared as soon as the polyps reached maturity.

An almost identical result was obtained in an earlier experiment on the effects of injury. Polyps which had regenerated the mouth and tentacles showed a marked reduction in the number of tentacles of the buds which they produced immediately after regeneration, but the average number of tentacles of successive buds formed after regeneration increased until at the end of two weeks, when four to eight buds had been produced, the polyps had returned to the normal condition of the clone from which they were derived.

The similarity of these results makes it certain that the only effect of selection was a temporary change in the vigor of the selected polyps (the selection of individuals with few tentacles involving the selection of weaker polyps) and that there is no cumulative inheritance of variations in the number of tentacles within the clone. Races of Hydra differing in their hereditary number of tentacles exist but individual variations do not involve changes in the hereditary constitution of such races.

Some evidence that the same conclusions apply to the inheritance of size was obtained, but the relation of variations in size to environmental changes has not been investigated thoroughly.